Applied Physics Letters 2017 vol.111 N25

Double Fe-impurity charge state in the topological insulator Bi2Se3

Stolyarov V., Remizov S., Shapiro D., Pons S., Vlaic S., Aubin H., Baranov D., Brun C., Yashina L., Bozhko S., Cren T., Pogosov W., Roditchev D.
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

© 2017 Author(s). The influence of individual impurities of Fe on the electronic properties of topological insulator Bi 2 Se 3 is studied by Scanning Tunneling Microscopy. The microscope tip is used in order to remotely charge/discharge Fe impurities. The charging process is shown to depend on the impurity location in the crystallographic unit cell, on the presence of other Fe impurities in the close vicinity, and on the overall doping level of the crystal. We present a qualitative explanation of the observed phenomena in terms of tip-induced local band bending. Our observations evidence that the specific impurity neighborhood and the position of the Fermi energy with respect to both the Dirac point and bulk bands have to be taken into account when considering the electron scattering on the disorder in topological insulators.

http://dx.doi.org/10.1063/1.5002567

References

[1] M. Z. Hasan and C. L. Kane, Rev. Mod. Phys. 82, 3045 (2010). 10.1103/RevModPhys.82.3045

[2] X.-L. Qi and S.-C. Zhang, Rev. Mod. Phys. 83, 1057 (2011). 10.1103/RevModPhys.83.1057

[3] L. Fu, C. L. Kane, and E. J. Mele, Phys. Rev. Lett. 98, 106803 (2007). 10.1103/PhysRevLett.98.106803

[4] J. E. Moore and L. Balents, Phys. Rev. B 75, 121306(R) (2007). 10.1103/PhysRevB.75.121306

[5] D. Hsieh, Y. Xia, D. Qian, L. Wray, J. H. Dil, F. Meier, J. Osterwalder, L. Patthey, J. G. Checkelsky, N. P. Ong, A. V. Fedorov, H. Lin, A. Bansil, D. Grauer, Y. S. Hor, R. J. Cava, and M. Z. Hasan, Nature 460, 1101 (2009). 10.1038/nature08234

[6] Y. L. Chen, J.-H. Chu, J. G. Analytis, Z. K. Liu, K. Igarashi, H.-H. Kuo, X. L. Qi, S. K. Mo, R. G. Moore, D. H. Lu, M. Hashimoto, T. Sasagawa, S. C. Zhang, I. R. Fisher, Z. Hussain, and Z. X. Shen, Science 329, 659 (2010). 10.1126/science.1189924

[7] Y. Cui, N. Nilius, H.-J. Freund, S. Prada, L. Giordano, and G. Pacchioni, Phys. Rev. B 88, 205421 (2013). 10.1103/PhysRevB.88.205421

[8] A. Polyakov, H. L. Meyerheim, E. D. Crozier, R. A. Gordon, K. Mohseni, S. Roy, A. Ernst, M. G. Vergniory, X. Zubizarreta, M. M. Otrokov, E. V. Chulkov, and J. Kirschner, Phys. Rev. B 92, 045423 (2015). 10.1103/PhysRevB.92.045423

[9] M. M. Yee, Z.-H. Zhu, A. Soumyanarayanan, Y. He, C.-L. Song, E. Pomjakushina, Z. Salman, A. Kanigel, K. Segawa, Y. Ando, and J. E. Hokman, Phys. Rev. B 91, 161306 (2015). 10.1103/PhysRevB.91.161306

[10] T. Eelbo, M. Wasniowska, M. Sikora, M. Dobrzanski, A. Kozlowski, A. Pulkin, G. Autes, I. Miotkowski, O. V. Yazyev, and R. Wiesendanger, Phys. Rev. B 89, 104424 (2014). 10.1103/PhysRevB.89.104424

[11] S.-Y. Xu, M. Neupane, C. Liu, D. Zhang, A. Richardella, L. A. Wray, N. Alidoust, M. Leandersson, T. Balasubramanian, J. Sanchez-Barriga, O. Rader, G. Landolt, B. Slomski, J. H. Dil, J. Osterwalder, T.-R. Chang, H.-T. Jeng, H. Lin, A. Bansil, N. Samarth, and M. Z. Hasan, Nat. Phys. 8, 616 (2012). 10.1038/nphys2351

[12] Y. S. Hor, P. Roushan, H. Beidenkopf, J. Seo, D. Qu, J. G. Checkelsky, L. A. Wray, D. Hsieh, Y. Xia, S.-Y. Xu, D. Qian, M. Z. Hasan, N. P. Ong, A. Yazdani, and R. J. Cava, Phys. Rev. B 81, 195203 (2010). 10.1103/PhysRevB.81.195203

[13] L. A. Wray, S. Y. Xu, Y. Xia, D. Hsieh, A. V. Fedorov, Y. San Hor, R. J. Cava, A. Bansil, H. Lin, and M. Z. Hasan, Nat. Phys. 7, 32 (2011). 10.1038/nphys1838

[14] R. Yu, W. Zhang, H. J. Zhang, S. C. Zhang, X. Dai, and Z. Fang, Science 329, 61 (2010). 10.1126/science.1187485

[15] C.-L. Song, Y.-P. Jiang, Y.-L. Wang, Z. Li, L. Wang, K. He, X. Chen, X.-C. Ma, and Q.-K. Xue, Phys. Rev. B 86, 045441 (2012). 10.1103/PhysRevB.86.045441

[16] F. Xiu, L. He, Y. Wang, L. Cheng, L. T. Chang, M. Lang, G. Huang, X. F. Kou, Y. Zhou, X. W. Jiang, Z. G. Chen, J. Zou, A. Shailos, and K. L. Wang, Nat. Nanotechnol. 6, 216 (2011). 10.1038/nnano.2011.19

[17] D. West, Y. Y. Sun, S. B. Zhang, T. Zhang, X. C. Ma, P. Cheng, Y. Y. Zhang, X. Chen, J. F. Jia, and Q. K. Xue, Phys. Rev. B 85, 081305 (2012). 10.1103/PhysRevB.85.081305

[18] T. Schlenk, M. Bianchi, M. Koleini, A. Eich, O. Pietzsch, T. O. Wehling, T. Frauenheim, A. Balatsky, J.-L. Mi, B. B. Iversen, J. Wiebe, A. A. Khajetoorians, P. Hofmann, and R. Wiesendanger, Phys. Rev. Lett. 110, 126804 (2013). 10.1103/PhysRevLett.110.126804

[19] D. H. Lee and J. A. Gupta, Nano Lett. 11, 2004 (2011). 10.1021/nl2003686

[20] K. Teichmann, M. Wenderoth, S. Loth, R. G. Ulbrich, J. K. Garleff, A. P. Wijnheijmer, and P. M. Koenraad, Phys. Rev. Lett. 101, 076103 (2008). 10.1103/PhysRevLett.101.076103

[21] A. P. Wijnheijmer, J. K. Garleff, K. Teichmann, M. Wenderoth, S. Loth, R. G. Ulbrich, P. A. Maksym, M. Roy, and P. M. Koenraad, Phys. Rev. Lett. 102, 166101 (2009). 10.1103/PhysRevLett.102.166101

[22] F. Marczinowski, J. Wiebe, J.-M. Tang, M. E. Flatté, F. Meier, M. Morgenstern, and R. Wiesendanger, Phys. Rev. Lett. 99, 157202 (2007). 10.1103/PhysRevLett.99.157202

[23] H. Zheng, A. Weismann, and R. Berndt, Phys. Rev. Lett. 110, 226101 (2013). 10.1103/PhysRevLett.110.226101

[24] H. Zheng, J. Zhang, and R. Berndt, Sci. Rep. 7, 10764 (2017). 10.1038/s41598-017-10814-z

[25] V. W. Brar, R. Decker, H.-M. Solowan, Y. Wang, L. Maserati, K. T. Chan, H. Lee, C. O. Girit, A. Zettl, S. G. Louie, M. L. Cohen, and M. F. Crommie, Nat. Phys. 7, 43 (2011). 10.1038/nphys1807

[26] D. A. Muzychenko, K. Schouteden, S. V. Savinov, N. S. Maslova, V. I. Panov, and C. Van Haesendonck, J. Nanosci. Nanotechnol. 9, 4700 (2009). 10.1166/jnn.2009.1086

[27] A. A. Kapustin, V. S. Stolyarov, S. I. Bozhko, D. N. Borisenko, and N. N. Kolesnikov, J. Exp. Theor. Phys. 121 (2), 279 (2015). 10.1134/S1063776115080075

[28] J.-M. Zhang, W. Ming, Z. Huang, G.-B. Liu, X. Kou, Y. Fan, K. L. Wang, and Y. Yao, Phys. Rev. B 88, 235131 (2013). 10.1103/PhysRevB.88.235131

[29] J. Suh, D. Fu, X. Liu, J. K. Furdyna, K. M. Yu, W. Walukiewicz, and J. Wu, Phys. Rev. B 89, 115307 (2014). 10.1103/PhysRevB.89.115307

[30] C. D. Spataru and F. Léonard, Phys. Rev. B 90, 085115 (2014). 10.1103/PhysRevB.90.085115

[31] J. W. G. Wildöer, A. J. A. van Roij, C. J. P. M. Harmans, and H. van Kempen, Phys. Rev. B 53, 10695 (1996). 10.1103/PhysRevB.53.10695